Watershed Monitoring for the Northwest Forest Plan

Data Summary Interpretation 2007
West Cascades Province

Prepared By:

Aquatic and Riparian Effectiveness Monitoring Program Staff

USDA Forest Service, Pacific Northwest Regional Office
Bureau of Land Management, Oregon State Office

4077 S.W. Research Way, Corvallis, OR 97333
http://www.reo.gov/monitoring/watershed

CONTENTS

ACKNOWLEDGEMENTS

The Aquatic and Riparian Effectiveness Monitoring Program is a multi-federal-agency effort. Contributors included USDA Forest Service Regions 5 and 6 and the Pacific Northwest Research Station, USDI Bureau of Land Management, National Oceanic and Atmospheric Administration Fisheries, US Environmental Protection Agency, US Geological Survey, USDI National Park Service, US Fish and Wildlife Service, California Indian Forestry and Fire Management Council, Northwest Indian Fisheries Commission, and Intertribal Timber Council.

Thanks to all of the individuals who contributed time and effort in support of the field data collection, particularly the 2007 field-sampling crews and supervisors, without whom the data used in our analyses would not exist.

Crew leaders: Jammie Meyer, Erik Meyer, Jonathon Nott and Scott Venables. **Crew members**: Katie Clower, April Farmer, Morgan Garay, Rachel Hanauer, Andrew Janos, Forest Kaye, Beth Kroitz, TJ Krug and Jenine Toby. **Field reconnaissance**: Brian Dwyer (Crew leader), Jeff O'Leary, Brian Sogge and Billy Wood. Field coordinators: Pete Gruendike and Hank LaVigne. **Office support staff**: Jeff Metzger.

Thanks to Jake Chambers and Lis Fano for compiling and analyzing the field data and Steve Wilcox for making maps and his efforts in putting this report on the internet. They also provided invaluable support for the field crews. Kirsten Gallo ran all of the decision-support models.

We thank the many people who provided logistical support in the field, including transportation, permits, campgrounds and support. Without their help, sampling of some watersheds would not have been possible.

Many district and resource-area biologists and district rangers provided valuable watershed information and support that enhanced field crew safety and effectiveness. Since there are too many individuals to mention here, we would like to thank them collectively. In addition, we thank the people who joined us in the field and provided feedback on the project.

INTRODUCTION

The Aquatic and Riparian Effectiveness Monitoring Program (AREMP or the monitoring program) is a multi-federal-agency program designed to assess the effectiveness of the Aquatic Conservation Strategy (ACS) of the Northwest Forest Plan (USDA, USDI 1994). The goal of the ACS is to maintain or restore the condition of watersheds in the Plan area. To evaluate the effectiveness of the strategy, the monitoring program determines whether key processes that maintain aquatic and riparian habitats are intact (Reeves et al. 2004). This information is used to assess the current condition of watersheds and to monitor changes in condition through time.

The ACS was designed to account for the complex and dynamic nature of aquatic ecosystems resulting from the wide range of physical characteristics, natural disturbance events, and climatic features of the region (Benda et al. 1998; Naiman et al. 1992). Consequently, the assumptions underlying the monitoring program are that watersheds are dynamic systems that will not remain in a static condition indefinitely. Thus, we do not expect all watersheds to be in good condition at any one time (Naiman et al. 1992; Reeves et al. 1995). The primary product of the monitoring program is a distribution that describes the range of watershed conditions in the Plan area. Implementing the strategy should result in a range of watershed conditions across the landscape that represents the natural range of conditions expected in a well-functioning aquatic network. If the strategy is effective, then the overall condition of watersheds across the region should either remain the same as it was when the strategy was implemented in 1994, or it should improve.

Watershed condition is evaluated at the USGS 6th-field hydrologic-unit subwatershed scale, hereafter referred to as watershed, using a province-specific decision-support model that aggregates data on in-channel, riparian, and upslope attributes. These attributes are indicators of watershed processes. A watershed is defined as being in "good" condition if the physical attributes are adequate to maintain or improve biological integrity, with a focus on diversity and abundance of native aquatic- and riparian-dependent species, salmonids in particular.

The purpose of this report is to provide local units with the results of our data collection and decision-support modeling efforts for watersheds surveyed in the West Cascades province (Figure 1, Table 1). Separate reports were prepared for each province. Included in this report are overviews of the in-channel data collection methods used in the field, the calculations performed on the data, GIS data collection methods, the decision-support model used to evaluate watershed condition, and a guide on how to interpret the model results. Benthic macroinvertebrate samples were collected in the field, but samples from some watersheds are currently at the laboratory being analyzed and were not available to be included in this report or the model output. Macroinvertebrate data will be posted to our website as it becomes available (http://www.reo.gov/monitoring/watershed-overview.shtml). Decision-support model information and links to additional report documents including watershed-specific summary tables, maps, photos, raw field-data files and GIS data are also located on the AREMP website.

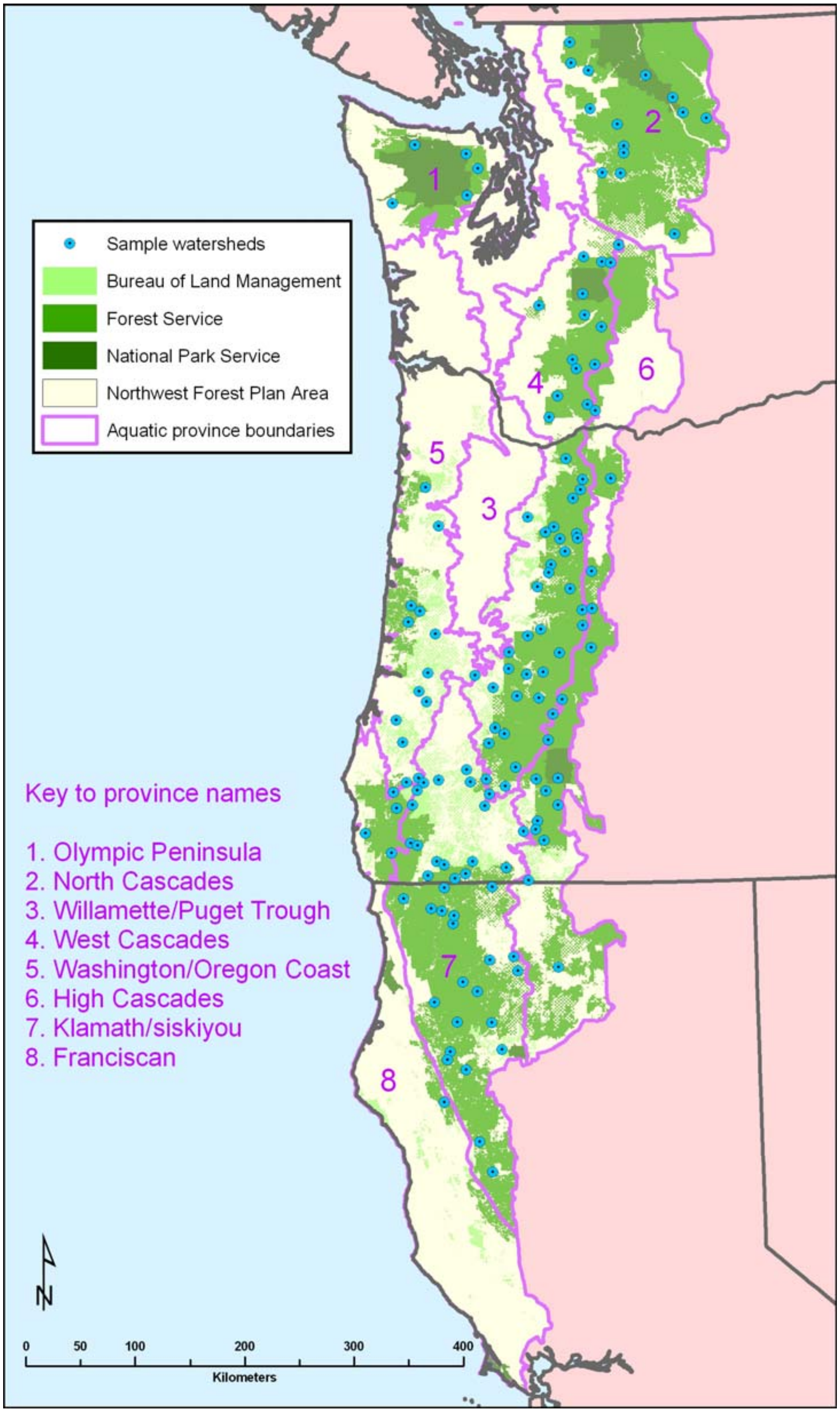


Figure 1. Randomly selected watersheds sampled in 2002-2007 by the Aquatic and Riparian Effectiveness Monitoring Program.

Table 1. Watersheds sampled in the West Cascades Province, 2002-2007.

USGS HUC	Watershed Name	Administrative Unit
170900020201	TABLE MOUNTAIN	Eugene BLM
170900020304	MIDDLE UPPER COAST FORK WILLAMETTE RIVER	Eugene BLM
170701051002	BIG LAVA BED FRONTAL	Gifford Pinchot NF
170800020102	TWIN FALLS CREEK	Gifford Pinchot NF
170800020108	ALEC CREEK	Gifford Pinchot NF
170800020203	ELK CREEK	Gifford Pinchot NF
170800020401	UPPER SIOUXON CREEK	Gifford Pinchot NF
170800020503	COPPER CREEK	Gifford Pinchot NF
170800040205	JOHNSON CREEK	Gifford Pinchot NF
170800040302	WILLAME CREEK	Gifford Pinchot NF
171100150110	LITTLE NISQUALLY RIVER	Gifford Pinchot NF
171003070504	HAWK CREEK	Medford BLM
171003070601	UPPER TRAIL CREEK	Medford BLM
171003070601	UPPER TRAIL CREEK	Medford BLM
171100130101	GREEN RIVER HEADWATERS	Mt. Baker-Snoqualmie NF
171100140104	UPPER WHITE RIVER - SILVER CREEK	Mt. Baker-Snoqualmie NF
171100140105	UPPER GREENWATER RIVER	Mt. Baker-Snoqualmie NF
171100140202	CLEARWATER RIVER	Mt. Baker-Snoqualmie NF
170800010102	DRAW CREEK	Mt. Hood NF
170800010201	STILL CREEK	Mt. Hood NF
170800010504	CEDAR CREEK	Mt. Hood NF
170900110101	UPPER HOT SPRINGS FORK COLLAWASH	Mt. Hood NF
170900110201	CUB CREEK	Mt. Hood NF
170900110304	HIGH ROCK CREEK	Mt. Hood NF
171100150101	NISQUALLY HEADWATERS	Mt. Rainer NP
170900090503	UPPER MOLALLA RIVER	Salem BLM
171003010801	CITY CREEK	Umpqua NF
171003011101	LITTLE RIVER CANYON	Umpqua NF
171003011104	EMILE	Umpqua NF
171003011106	UPPER CAVITT CREEK	Umpqua NF
171003020203	SQUAW	Umpqua NF
171003020302	DUMONT	Umpqua NF
171003020403	DREW CREEK	Umpqua NF
170900020101	LAYNG CREEK	Umpqua NF
170900010106	UPPER MIDDLE FOR WILLAMETTE RIVER / ECHO CREEK	Willamette NF
170900010303	LOWER SALT CREEK	Willamette NF
170900010504	MIDDLE FORK WILLAMETTE RIVER / LARISON CREEK	Willamette NF
170900010603	NORTH FORK OF MIDDLE FORK WILLAMETTE RIVER/FISHER CREEK	Willamette NF
170900010701	LOOKOUT POINT RESERVOIR	Willamette NF
170900010902	FALL CREEK / HEHE CREEK	Willamette NF
170900040102	FISH LAKE CREEK	Willamette NF
170900040107	UPPER WHITE BRANCH	Willamette NF
170900040201	UPPER SEPARATION CREEK	Willamette NF
170900040501	QUARTZ CREEK	Willamette NF

Table 1. Watersheds sampled in the West Cascades Province, 2002-2007 (Cont.)

USGS HUC	Watershed Name	Administrative Unit
170900050107	BOULDER CREEK	Willamette NF
170900050202	NORTH FORK BREITENBUSH RIVER	Willamette NF
170900050203	HUMBUG CREEK	Willamette NF
170900050503	GOLD CREEK	Willamette NF
170900060401	UPPER QUARTZVILLE CREEK	Willamette NF
170900060503	SIXES CREEK	Willamette NF
170900060604	FALLS CREEK	Willamette NF

NEW IN 2007

Future Direction for the Monitoring Program

Following the 10-year evaluation of the Northwest Forest Plan, the Regional Interagency Executive Committee directed AREMP staff to develop options for modifying the monitoring program to provide information on the status and trend of watershed conditions at different spatial scales ranging from the Forest Service/Bureau of Land Management (BLM) administrative unit to the entire Plan area, while operating under a constrained budget.

To provide watershed condition information at multiple scales, AREMP personnel developed a Geographic Information Systems (GIS)/remote-sensing-based monitoring program option that relies on continued field sampling to inform GIS analyses. This option allows the program to evaluate every watershed with more than 25 percent federal ownership in the Plan area as frequently as data are collected or updated. This option is based on using decision-support models to aggregate upslope and riparian attributes (such as roads, vegetation, and mass wasting) and calculate a watershed condition score. Upslope and riparian attributes are measured for every watershed using GIS and remote sensing data. In-channel physical, chemical, and biological attributes are measured in the field at randomly chosen sites within randomly chosen watersheds throughout the Plan area and will be used to validate the watershed-condition assessment calls made using GIS data only.

Decision-Support Models in Forest Plan Revision

Program personnel have been working with specialists on the Okanogan-Wenatchee, Colville, Umatilla, Malheur, and Wallowa-Whitman National Forests to apply decision-support models in their forest plan revisions. These forests are using the AREMP watershed-condition model as part of the key watershed designation process and to conduct sustainability analyses for aquatic focal species listed as “threatened” or “endangered” under the Endangered Species Act or as a species of concern. Key watershed determination and the sustainability analyses are requirements of a new proposed Aquatic and Riparian Conservation Strategy that will be applied across Oregon and Washington by US Forest Service in the Pacific Northwest Region. The new strategy will become part of the management plan of each forest and will replace previous management plans such as the Northwest Forest Plan, PacFish, and InFish. Decision-support models have been constructed for all Forests in the NWFP area, and we are working toward constructing them for the east-side forests.

METHODS

Study Design

The goal of the program is to monitor 50 watersheds per year, each approximately 10,000-40,000 acres in size, on a five-year rotation (Reeves et al. 2004). Watersheds are chosen from 250 randomly-selected 6th field watersheds located in the Plan area (Figure 1). To be included in the sample, a watershed must contain a minimum 25% federal ownership along the stream based on the 1:100,000 stream layer. However, due to partial program funding, we have sampled only 142 watersheds from 2002-2007.

We collected in-channel, riparian, and upslope attributes within each watershed. Upslope and riparian data were collected from vegetation and roads layers using GIS. The evaluation of upslope and riparian conditions in watersheds was tailored to specific physiographic provinces. The province boundaries used in this analysis were developed from those used in the aquatic ecosystem assessment (FEMAT 1993), which were based on broadly-drawn precipitation and geologic areas.

Field Data Collection

Field data provide information on the physical habitat and biota of streams. Physical habitat indicators measured included pool frequency, sinuosity, gradient, wood size and frequency, percent pool-tail fines, and substrate D50. Biological indicators sampled were benthic macroinvertebrates and terrestrial amphibians. Water temperature and conductivity data were also collected. Fish and periphyton sampling were removed from the sampling protocol in 2007.

Three surveys implementing the same sampling protocol are conducted within each watershed, with the data from each serving a different purpose. The survey types are as follows:

- Initial Surveys – These surveys are conducted within watersheds not yet sampled by the monitoring program. Sample sites within a watershed are systematically chosen from a set of the 80 randomly-selected sites.
- Quality Assurance/Quality Control (QAQC) Surveys – The intent of these repeat surveys is to ascertain inter-crew attribute measurement precision. An independent crew resurveys a randomly-selected subset of the initial survey sites within a given watershed later in the same field season. During the resample visit, only the start point of the survey is given to the survey crew. Subsequent sampling is conducted in the same manner as the original survey.
- Trend Surveys – The intent of these surveys is to assess trend in condition of a subset of the 250 watersheds prior to completion of the full cycle of sampling. These surveys are conducted at QAQC sites during the following year by a field crew that did not perform the initial or QAQC surveys.

Eighty initial-survey sampling sites were randomly chosen along the stream network in each watershed, identified with GPS coordinates, and randomly-assigned numbers between 1 and 80. In the field, we considered sites for sampling in ascending numerical order and omitted sites that could not be sampled. The goal was to sample as many sites as possible within a typical 8-day field stint, which included travel time, resulting in an average of just over six sites sampled per watershed. A site was rejected if: 1) it was located on private land or could not be accessed due to private land; 2) it was located on a glacier or in a lake; 3) it was not safely accessible; 4) the stream had pools too deep to wade, substrate measurement requiring a wet suit, or was wadeable in only a few riffles; or 5) travel time on foot to and from the site was greater than 4 hours.

Sampling was conducted at 11 major and 10 intermediate transects equally spaced along the length of the site or sample reach (Figure 2). The length of each site was determined using 2-m bankfull-width categories resulting in a reach length approximately 20 times the bankfull width, with minimum and maximum reach lengths of 160 and 480 m. We established the start point for sampling at the GPS coordinate and measured the reach upstream along the thalweg one transect at a time. We documented the start of the survey reach by recording the GPS coordinate with a Garmin GPS 12-map, taking a minimum of nine photos from the start point including shots facing left bank, downstream, right bank and upstream, and posting a marker or monument near the start point. Photographs of the start-point location and unique adjacent features were used in lieu of monuments in wilderness areas. The end point of the reach was established at the 21st transect location. Side channels were included in the survey only if they began and ended within the survey reach and had an average bankfull width at least 20% as wide as that found in the adjacent primary channel.

Physical Habitat

Sinuosity, gradient and average bankfull width of each stream reach were calculated using measurements made with a laser rangefinder. Sinuosity was calculated as the length of the reach along the thalweg, measured with a measuring tape, divided by the straight-line distance between the thalweg points at the start and end of the reach, measured with the laser. We used bankfull width measurements taken at the eleven major transects to calculate the average bankfull width (Table 2). Reach gradient was calculated by taking the difference in elevation between the wetted edges of transects A and K, at the bottom and top of the reach, and dividing this difference by the reach length. Reach length and bed elevations were also measured using a laser rangefinder. We also measured wetted edges and thalweg points, or deep-channel areas, of major and minor transects.

Pool-habitat morphometry information, including the location of the tail crest, pool head and maximum depth of each pool, was also captured with a laser rangefinder. A habitat unit was considered a pool if it had: 1) a concave profile laterally and longitudinally; 2) a head and tail crest; 3) a wetted-channel width that occupied 90% of the wetted width at any location within the length of the unit; 4) a length greater than its width; 5) a maximum depth at least 50% greater than the pool-tail depth; and 6) the thalweg running through the unit. Pool measurements were used to calculate pool frequency and residual pool depths (Table 2).

Residual pool depth was calculated as the elevation difference between the thalweg depth at the pool-tail crest and the maximum pool depth.

Substrate particles for the D_{16}, D_{50} and D_{84} calculations were measured using a modification of the substrate protocol used by the Environmental Monitoring and Assessment Program of the Environmental Protection Agency (Peck et al. 1999). Five substrate particles were randomly-selected from each of the 21 transects at 10%, 30%, 50%, 70% and 90% of the distance across the bankfull channel. Each particle was measured along its intermediate axis with a meter stick. Percent fines, particles less than 2 mm diameter, were measured in the tails of scour pools as described by the USDA Forest Service Region 5 SCI protocol (1998). We used a 14-inch square

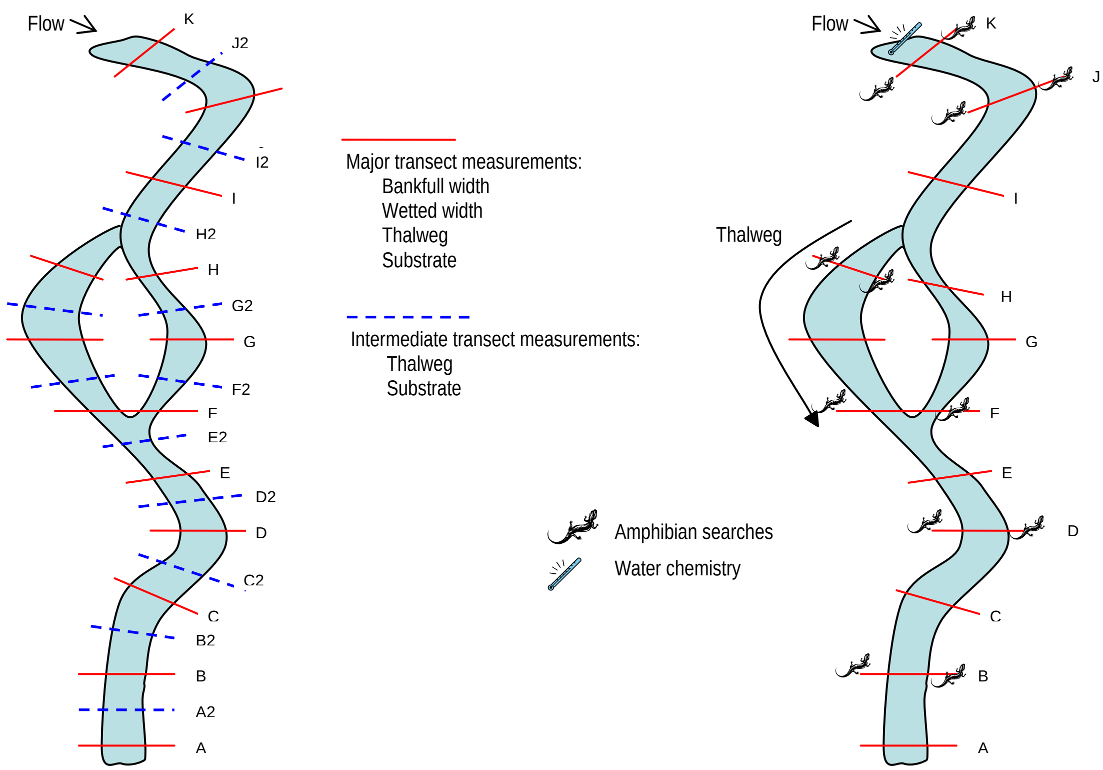


Figure 2. Overview of site layout and sampling strategy. The start point is established at the downstream end of the reach at transect A. Major and minor transects are equally spaced along the thalweg. Measurements and sampling conducted at each transect are displayed.

Klamath grid with 7 equally-spaced horizontal and vertical twine partitions to measure percent fines in pool tails. Three grid measurements were taken in each pool tail at 25%, 50% and 75% of the distance across the wetted width at either 10% of the pool length upstream of the pool-tail crest or one meter upstream of the crest, whichever was less. We counted the number of twine intersections resting atop substrate less than 2 mm and greater than 512 mm in length on the intermediate axis. A twine intersection with substrate of the latter size class under it was recorded as a "non-measurement." These measurements were used to calculate percent fines per pool tail and then averaged for the first 10 pools (Table 2).

The large-wood protocol was adapted from the Stream Habitat Survey methodology of Oregon Department of Fish and Wildlife (Moore et al. 1999). Pieces of wood found within the main channel and any side channels were counted if they had a minimum length of 3 m, were at least 0.3 m in diameter at one third of the distance from the large end, and either hung over or touched below the bankfull elevation of the channel. The length and diameter of the first 10 pieces encountered in the reach and every 5th piece thereafter was measured using a measuring tape so that subsequent estimates could be corrected. Length and diameter were visually

Table 2. Equations used to calculate physical channel attributes. Precision is the number of significant digits used in the calculation.

ATTRIBUTE	DEFINITION	EQUATION	PRECISION	# OF MEASUREMENTS
Average Bankfull Width	Average of the bankfull widths measured at the eleven major transects in the reach.	(Sum of BF widths) / Number of transects	0.1 m	11
Bankfull Width: Depth Ratio	Ratio of bankfull width to bankfull depth each channel cross-section.	Depth: Area of cross-section / BF width Width: BF width W:D = BF width / BF depth	1	1 width, 5 depth
Sinuosity	Reach length measured along thalweg divided by straight valley length from bottom to top of reach.	Reach Length / Valley length	0.1	1
Reach Gradient (% Slope)	Elevation change of substrate surface at the thalweg, from bottom to the top of the reach, divided by the reach length measured along the thalweg.	(Change in Elevation / Reach Length) * 100	0.1 %	1
Average Residual Pool Depth	Average of residual pool depths for all pools.	(Sum of (Pool Max Depth - Pool Tail Depth)) / Number of Pools	0.01 m	All qualifying pools, according to the AREMP protocol.
Pool Frequency	Number of pools per 100 m.	(# pools / reach length) * 100	0.001 m^{-1}	All qualifying pools, according to the AREMP protocol.
Large Wood Frequency	Number of wood pieces greater than 0.3 m diameter and 3 m long, per 100 m.	(# pieces / reach length) * 100	0.001 m^{-1}	All qualifying pieces, according to the AREMP protocol.
Percent PTC Fines	Percent surface fines measured 3 times, 10% or 1 m upstream of the tail crest of a pool.	Average of: (Sum of # Fines Measurements / (150-(sum of # non-measurements))) * 100	0.1 %	The first 10 qualifying pools, according to the AREMP protocol
D50 Pebble Count	D_{50} (mm) is the 50th percentile (median distribution) of the substrate particles measured.	Intermediate axis diameter of the median particle collected from particle counts.	1 mm	5 particles per transect on 21 transects.
D84 Pebble Count	D_{84} (mm) is the 84th percentile of the substrate particles measured.	Intermediate axis diameter of the particle for which 84% of the particles are smaller (84th percentile).	1 mm	5 particles per transect on 21 transects.
D16 Pebble Count	D_{16} (mm) is the 16th percentile of the substrate particles measured.	Intermediate axis diameter of the particle for which 16% of the particles are smaller (16th percentile).	1 mm	5 particles per transect on 21 transects.

estimated for all remaining pieces. In addition, codes were recorded that described: 1) the location of the wood relative to the channel; 2) whether the piece was natural or artificial (e.g., part of a man-made structure); 3) whether the piece had a cut end; 4) whether the piece was single, part of an accumulation of 2-4 pieces touching or part of a jam of 5 or more pieces; and 5) the percent of each piece of wood that would be submerged at bankfull flows.

Select water-quality parameters were measured within all sampled watersheds. Water temperature, conductivity, and specific conductance measurements were conducted during the initial site visit at five-minute intervals for two hours at the upstream end of each sample site using a YSI 556 multi-probe meter. These measurements were averaged for each reach. Water temperature measurements were also recorded hourly from 1 June through 15 September with continuous recording temperature loggers placed at the lowest point in the watershed on federal land. The latter temperature data were used to calculate the maximum seven-day average temperature for each watershed.

Biological Sampling

Benthic macroinvertebrates were collected and analyzed using the protocol described by Hawkins et al. (2001). We used a kick net to collect two subsamples at randomly-selected locations within each of the first four fast-water units encountered in each reach for a total of eight subsamples. All rocks larger than a golf ball within each 0.09 m2 sample area were rubbed to remove attached organisms, and then placed outside the sampling area. The exposed areas of embedded rocks were also rubbed. Finally, the substrate within the sampling area was disturbed for approximately 30 seconds. We decanted the eight combined subsamples with a sieve, a wash basin, and a bucket to remove inorganic substrate before fixing the sample with ethanol. Samples were sent to a laboratory where all insects were identified to the genus level, except Chironomidae, which were identified to subfamily.

Time- and area-constrained searches were conducted for terrestrial amphibians at each site within a watershed. Crew members searched upstream from six of the major transects (Figure 2) along 2-m strips adjacent to both wetted stream edges. Each search lasted five minutes for a total of ten minutes at each transect. During this time, searchers rolled over rocks and logs and dug through leaves and soil. All captured terrestrial amphibians were identified, counted, measured for snout-vent and total length, photographed, and then returned to the area captured. The protocol used was adopted from Aquatic/Land Interaction Team at the PNW-FSL (Dede Olson, personal communication).

GIS Data Collection

Analyses of road and vegetation attributes were based on Geographic Information System (GIS) coverages. These analyses were tailored to physiographic provinces which were based on broadly drawn precipitation and geologic areas (FEMAT 1993). Watershed boundaries used in the analysis were from the first draft of the 6th-field Hydrologic Unit Code boundaries developed in 2002. We used 1:24,000 densified stream layers from the Forest Service Region 6 Hydrography framework project. In the West Cascades province, we defined the riparian area by creating a fixed buffer along both sides of all streams on the 1:24,000 stream layer. A 50 m buffer was used in the road analysis and a 60 m buffer was used in the vegetation analysis. Upslope area was defined as the area outside of the riparian boundaries.

Road Analysis

Road density and frequency of road-stream crossings were calculated using GIS coverages that were pieced together from Forest Service road and BLM ground transportation coverages. The Forest Service coverages, dated 2002, were obtained from each of the national forests in the Forest Plan area and clipped to the administrative boundaries of the forests. The BLM ground transportation coverage contains data from 1998 that cover all of the BLM districts and other non- BLM lands.

In the West Cascades province, road densities were calculated for riparian, upslope, and steepslope areas (areas with slope greater than 50 percent) for each watershed. The road layer was laid over the 50 m riparian buffer and riparian road density was calculated by dividing the miles of road within the riparian boundaries by the total stream miles. Density of upslope roads was calculated by dividing the length of road in the upslope area by the total watershed area. We used 30 m digital elevation models compiled by US Geological Survey (2001) to delineate areas with slopes greater than 50 percent. Density of roads in steep-slope areas was calculated as the length of road in steep areas per unit watershed area. We overlaid road and 1:24,000 stream layers in each watershed and counted the number of road and stream crossings. Forty-eight sample watersheds spread across the Plan area were then inspected for potential erroneous crossings from digitizing errors. The percentage of suspected false crossings was less than two percent for the total sample.

Vegetation Analysis

Conifer size and percentage of canopy cover in the riparian and upslope areas of the watershed were included in the monitoring plan's evaluation of watershed condition. Riparian and upslope vegetation data were collected from coverages developed by the Interagency Vegetation Mapping Project (version 2.2 in Oregon and version 2.0 in Washington) that were updated using the vegetation change layer developed for the Northwest Forest Plan vegetation monitoring program (Moeur et al. 2005). These layers were built using Landsat Thematic Mapper remote sensing data. The coverages were clipped to watershed boundaries and the 60 m riparian buffer was used to calculate the percentage of forested riparian area containing conifers with diameter at breast height (DBH) greater than 20 inches, and the percentage of forested upslope area with conifers less than 10 inches DBH. Forested area of riparian and upslope areas was determined by subtracting the non-forested areas, defined as areas incapable of producing trees (such as glaciers, lakes, lava beds or agricultural lands), from the total riparian (area inside the riparian buffer) or upslope (area outside the riparian buffer) area.

Assessment of Watershed Condition

Decision-support models were used to assess the condition of individual watersheds. These models are computer-based models that capture evaluation procedures and apply a consistent decision or evaluation process across time and space. Reeves et al. (2004) recommended using these models because they are transparent and easy to replicate. The transparent quality of the model facilitates explaining how the assessment was conducted.

Decision-support models use data to evaluate a premise. For this analysis, we evaluated the premise that watersheds are in good condition. Data used in the assessment lend varying levels of support to that premise, ranging from full support to no support. We developed criteria to evaluate each attribute based on data and professional judgment. Data on individual attributes were compared to these criteria and given an evaluation score between +1 and –1, where +1 indicated full support and –1 indicated no support for the premise. Evaluation scores for the attributes were aggregated into an overall assessment of watershed condition. User-defined rules produced an aggregated score weighted toward the resource with the lowest evaluation score, or a score based on the weighted or unweighted average of the indicator evaluation scores. Selection of the rules was based on professional judgment that relied on knowledge of the watersheds and ecological processes. In the models used in this analysis, evaluation scores were typically aggregated using either a weighted or unweighted average. Weights were assigned based on the expert opinion about the relative importance of individual attributes contributing to the condition of watersheds. In a few cases, an aggregated score weighted toward the lowest evaluation score was used to allow a single variable to override other variables.

A decision-support model was built, refined, and peer-reviewed for each physiographic province to account for the ecological differences that exist between provinces. The workshops consisted of an informal group process through which local experts came to consensus on the model structure and evaluation criteria. After the workshops, models were built and run and the results were returned to the workshop participants. Participants compared the results of the model to their knowledge of the condition of the watersheds and suggested refinements to the model as necessary. Changes were made to the model and the results were re-evaluated. Another round of workshops will be conducted in 2008 to update the models based on new information and add new attributes to the models.

MODEL DESCRIPTION AND INTERPRETATION

Watershed- and reach-condition scores are presented in the model output table in the watershed data-summary document. These scores were calculated by evaluating individual attributes and then aggregating their evaluation scores.

How the Model Works

The West Cascades Province model includes an evaluation of both watershed- and reach-scale attributes. The model hierarchically aggregates data from a number of attributes into broader indices of reach and watershed condition. For example, the reach-condition score also serves as one component of the broader watershed-condition score. In this case, the reach-condition score used in the watershed model is the average of the evaluation scores of all the reaches in the watershed. A graphical depiction of the watershed and reach model structure for the West Cascades Province is presented in Figures 3 and 4, respectively. In this iteration, some model sections were "turned off" because the corresponding data were not available. These unused portions of the models are indicated in gray on the diagram.

The model begins by reading a set of data observations, which we call "attributes" for a watershed. These attributes are the right-most nodes in the model-structure diagrams. For example, maximum seven-day-average water temperature is an attribute of the watershed-condition model. When the provincial experts constructed the model structure, they also developed evaluation criteria for each attribute. The attributes and evaluation criteria that make up the watershed and reach condition models are described in Tables 3 and 4, respectively.

The watershed-model attributes column contains the attribute name, units of measure and qualifiers, if there are any. For example, temperature is evaluated differently in watersheds depending on whether or not bull trout are present. The data value and evaluation score columns show how the data values correspond to evaluated scores. The curve-shape column gives a graphical depiction of the relationship, with data values represented on the x-axis and corresponding evaluation scores on the y-axis (Table 3). The evaluation curves depict how each data value is scored on a scale from +1 to -1, according to its contribution toward overall watershed condition. As attribute data are read into the model, they are compared to the evaluation criteria to produce an evaluation score between +1 and -1. The source column gives the basis on which the curve was constructed, which is most often the professional judgment of workshop participants, but also includes datasets, published reports or standards.

For example, in the West Cascades Province, if there are no roads within the riparian area (riparian road density = 0), then the evaluation score would be +1 because it is at or less than the node-x value of 0; if road density was 0.1 miles of road per mile of stream or greater, the score would be -1; and if the density falls between 0 and 0.1, the attribute receives a score that is a linear interpolation between +1 and -1 (for example .05 would evaluate to 0). Note that there is an important difference between a data value of "zero" and "no data." Data values of zero, as in the lower-slope road density example above, are compared to their evaluation curve in the same way as all other data values.

The model aggregates the attribute evaluation scores together in a hierarchical fashion after each attribute datum is evaluated. The combined score is passed up to the next level in the model hierarchy where it is combined with results from other parts of the model (Figure 3). To assign levels of importance to different variables, the model uses two different operators to aggregate the evaluation scores: 1) MIN, where it takes the minimum score from those being aggregated; and 2) AVE, where it averages the scores. These functions reflect whether the attribute is a "limiting factor" type and the worst-condition score determines the combined score (MIN), or a "partially compensatory" situation, where scores are all counted equally (AVE). In addition to operators, each node in the model can also be assigned a weight. For example, 70% of the weight could come from one attribute and 30% from another.

Reach-condition scores were determined in a similar fashion to watershed-condition scores. Attribute data values were assigned evaluation scores which were aggregated using operators, and assigned weights to obtain an overall reach-condition score (Figure 4).

How to Interpret the Assessment of Watershed Condition

The assessment of watershed condition table in the watershed data summary document presents the evaluation scores from the top down, in an outline format. The indented attributes represent the contributing attributes with their data values and corresponding evaluation scores. At each higher level of the outline, the aggregation of the contributing evaluation scores is displayed, consistent with Figure 3. Reach-condition scores for each of the sites that were surveyed in the watershed are presented in the table below with the sites listed from left to right. The tab left of the model output tab in the Excel document contains a data dictionary explaining each of the attributes that were evaluated in the model, listed in the same order as in the Watershed Condition table.

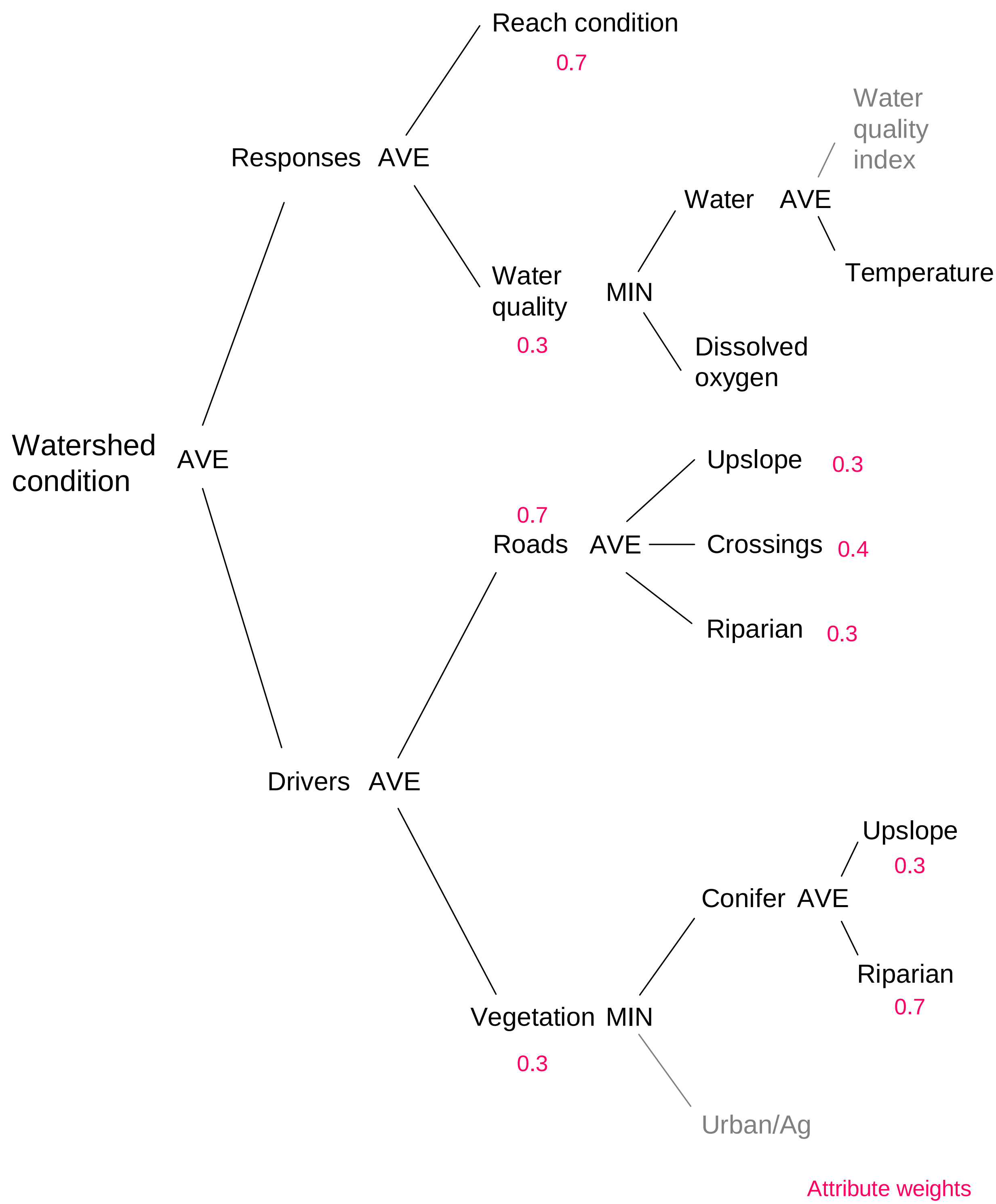


Figure 3. Graphical depiction of the watershed model structure for the West Cascades Province. The right-most nodes in the diagram represent watershed attributes that are evaluated and given an evaluation score. Evaluation scores are aggregated using the operators and weights depicted on the diagram to calculate an overall watershed condition score.

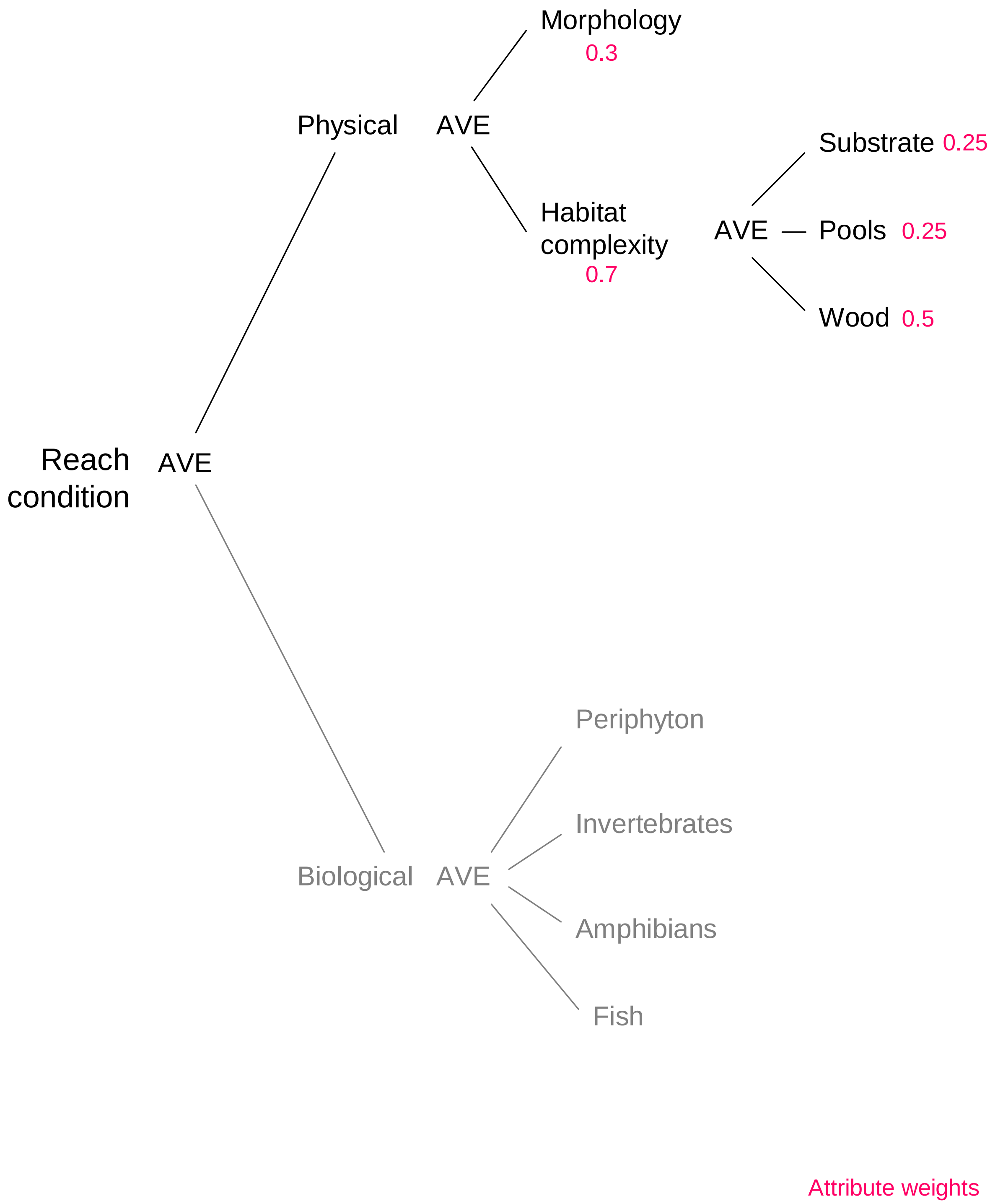


Figure 4. Graphical depiction of the reach model structure for the West Cascades Province. The right-most nodes in the diagram represent reach attributes that are evaluated and given an evaluation score. Evaluation scores are aggregated using the operators and weights depicted on the diagram to calculate an overall watershed condition score. Reach condition scores are an attribute of the watershed condition model.

Table 3. Watershed model attributes and evaluation criteria for the West Cascades Province.

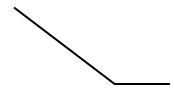
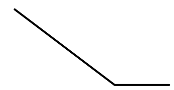
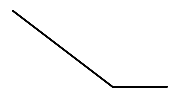
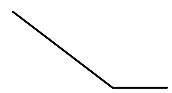
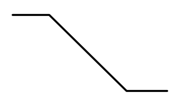
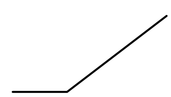
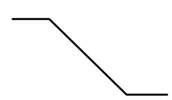
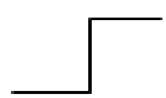
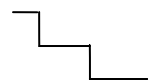
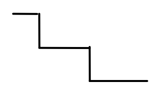
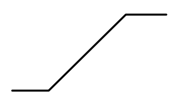
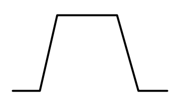
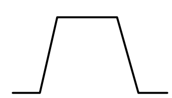
Watershed model attributes	Data value Node x-value	Evaluation score Node y-value	Curve shape	Source
High-slope road density slope >50% mi road / mi² watershed	0 0.5	1 -1		AREMP Workshop 5/22/03
Upslope road density mi road / mi² watershed	0 4	1 -1		Dose & Roper 1993 AREMP Workshop 5/22/03
Riparian road density mi road / mi stream 50m buffer	0 0.1	1 -1		AREMP Workshop 7/1/04
Road crossing frequency # crossings / mi stream	0 1.75	1 -1		AREMP Workshop 7/1/04 WNF ave 1.44 (1:24k) MHNF ave 0.8
Upslope vegetation Small conifer cover % area with conifers <10" dbh	10 40	1 -1		AREMP Workshop 5/22/03
Riparian vegetation Large conifer cover % area with conifers ≥20" dbh 60m buffer	60 100	-1 1		AREMP Workshop 7/1/04 dbh from wildlife handbook Dose & Roper pub on harvest/roads vs condition >30% ws impacted
Water temperature maximum 7-day average °C	16 18 23	1 0 -1		AREMP Workshop 5/22/03
Dissolved oxygen % saturation or mg/L	< 50% ≥ 50% < 4 ≥ 4	-1 1 -1 1		AREMP Workshop 5/22/03

Table 4. Reach model attributes and evaluation criteria for the West Cascades Province.

Reach Model Attributes	Data value Node x-value	Evaluation score Node y-value	Curve shape	Source
Morphology				Professional judgment
Slope	Use to determine Rosgen stream type.			
Entrenchment ratio	If D,F,G channel then -1, otherwise +1			
Sinuosity				
Bankfull width: depth				
Pool frequency				
# bankfull widths per pool				
≤ 3% slope	< 5	1		Montgomery and Buffington (1993)
	5	0		
	7	0		
	> 7	-1		
> 3% slope	<1	1		Montgomery and Buffington (1993)
	1	0		
	4	0		
	>4	-1		
Wood frequency	1	-1		Professional Judgment
# pieces per 100 m	4	1		
Substrate D50	40	-1		AREMP Workshop 5/22/03
mm	60	1		
≤ 5% slope	140	1		
	200	-1		
> 5% slope	40	-1		Professional Judgment
	60	1		
	200	1		
	500	-1		

RESULTS

Watershed Condition

Watershed-condition scores are the aggregate of all road, vegetation, and in-channel attributes collected. These scores ranged from -0.6 to 0.8 across the area encompassed by the Plan. In the West Cascades Province, watershed-condition scores ranged from -0.5 to 0.5 (Figure 5).

Road Condition

Road-condition scores, the aggregate of riparian road density and road crossing frequency, ranged from -1 to 1 for both the Plan area and the West Cascades Province (Figure 6).

Road-Crossing Condition

Road-crossing condition scores, which consist of counts of roads crossing streams, ranged from -1 to 1 in both the province and the Plan area (Figure 7).

Vegetation Condition

Vegetation-condition scores, which consist of the evaluation of riparian vegetation and the percentage of the watershed in urban and agricultural land use, ranged from -1 to 1 in plan area and -1 to 0.5 in the province (Figure 8).

Riparian-vegetation Condition

Riparian vegetative condition scores, which consist of the proportion of riparian area covered with conifers > 20 in. dbh, ranged from -1 to 1 in the Plan area and -1 to 0 in the province (Figure 9).

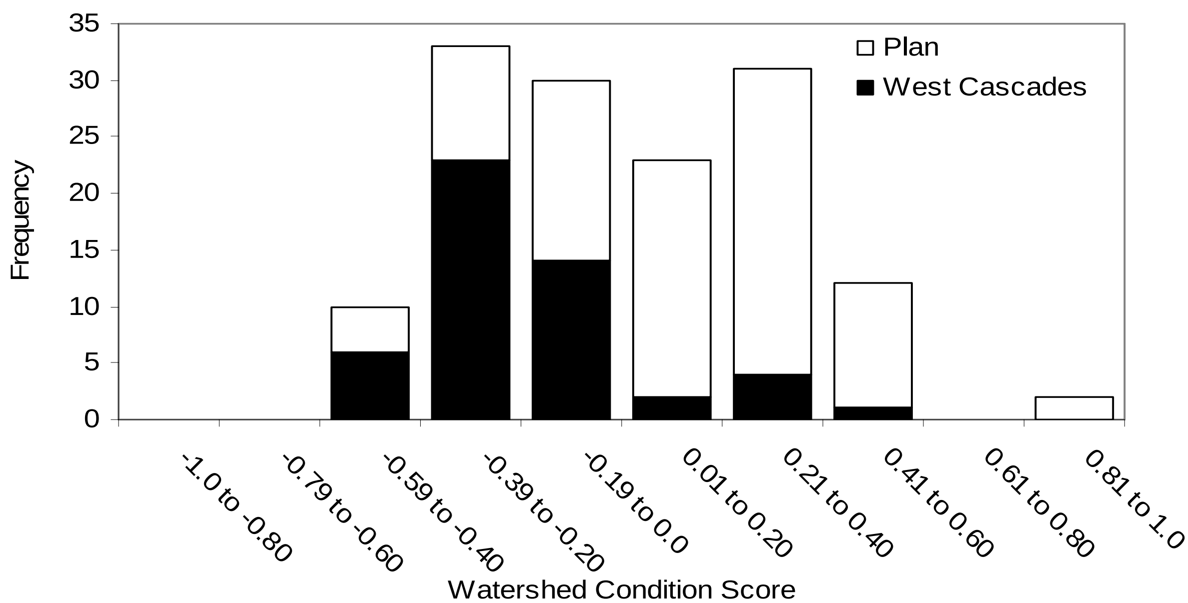


Figure 5. Distribution of watershed-condition scores for the West Cascades Province and the Northwest Forest Plan area.

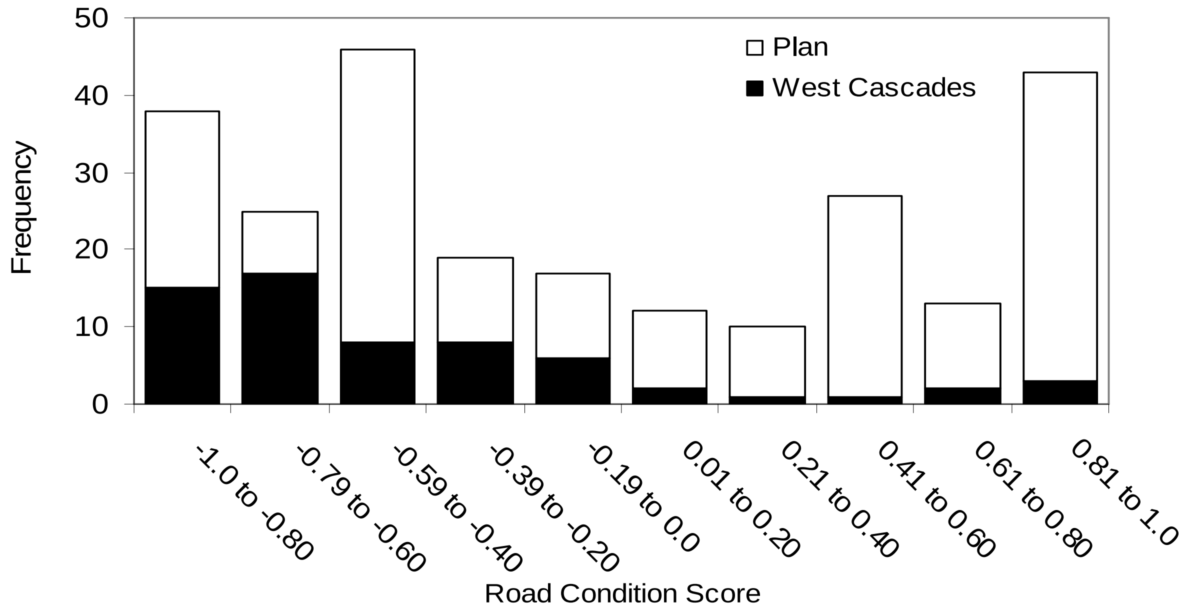


Figure 6. Distribution of road-condition scores for the West Cascades Province and the Northwest Forest Plan area.

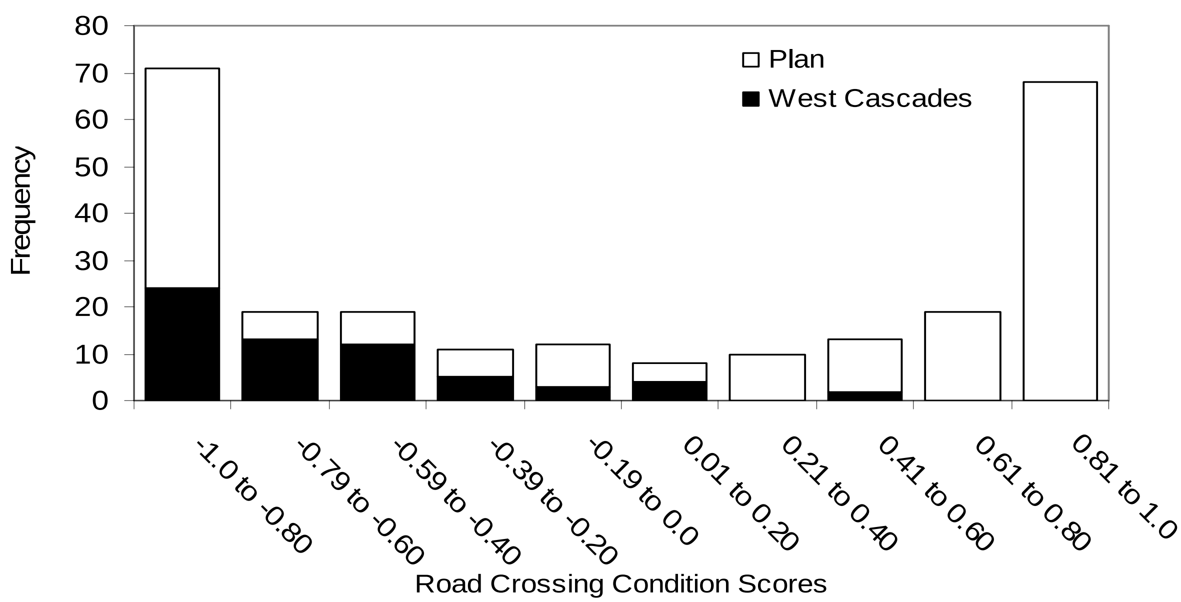


Figure 7. Distribution of road-crossing frequency scores in the North Cascades Province and the Northwest Forest Plan area.

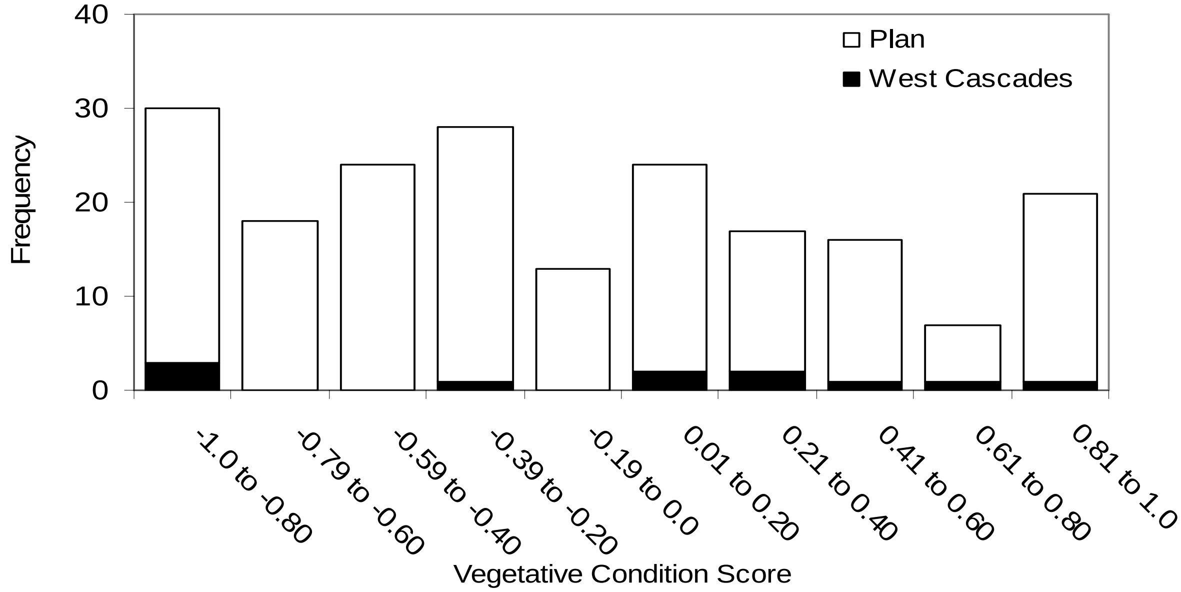


Figure 8. Distribution of vegetation-condition scores in the West Cascades Province and the Northwest Forest Plan area.

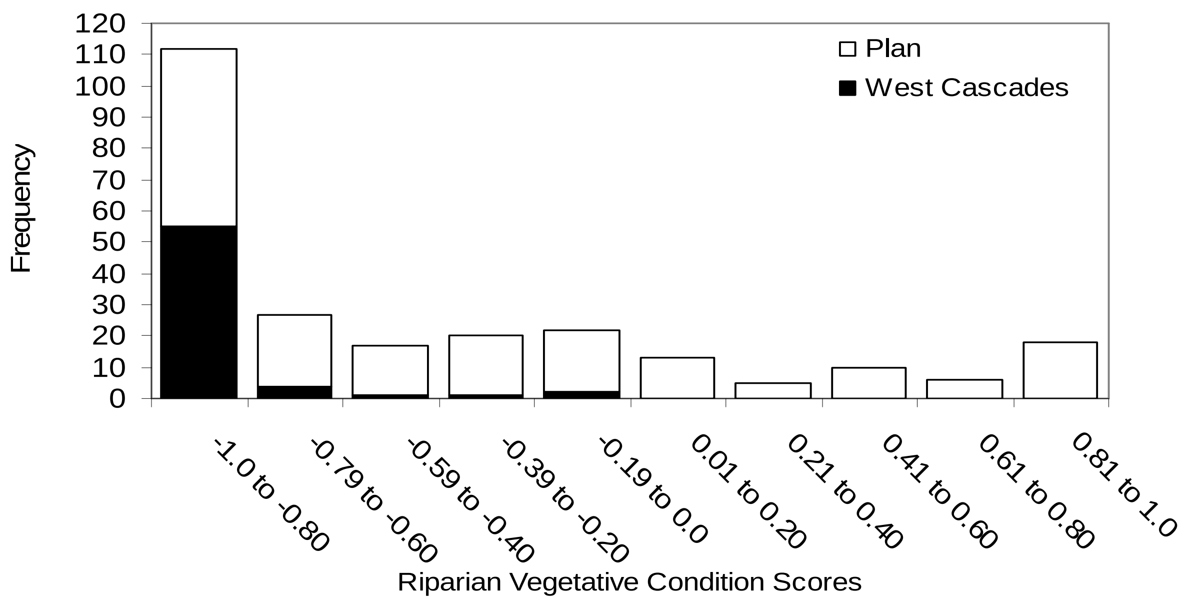


Figure 9. Distribution of riparian-vegetation conditions scores in the North Cascades Province and the Northwest Forest Plan area.

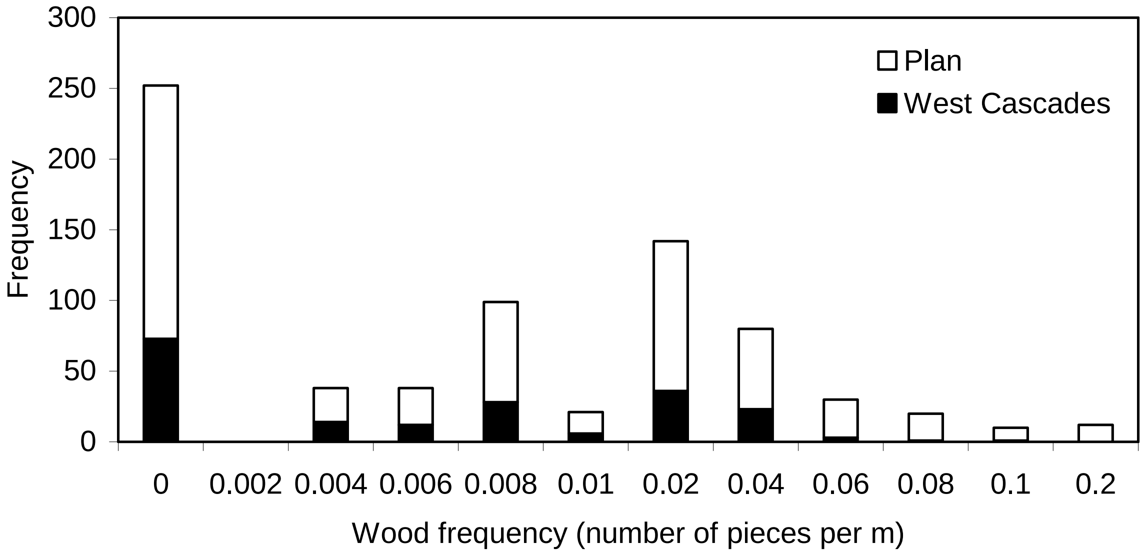


Figure 10. Distribution of wood frequencies in stream reaches in the West Cascades Province and the Northwest Forest Plan area.

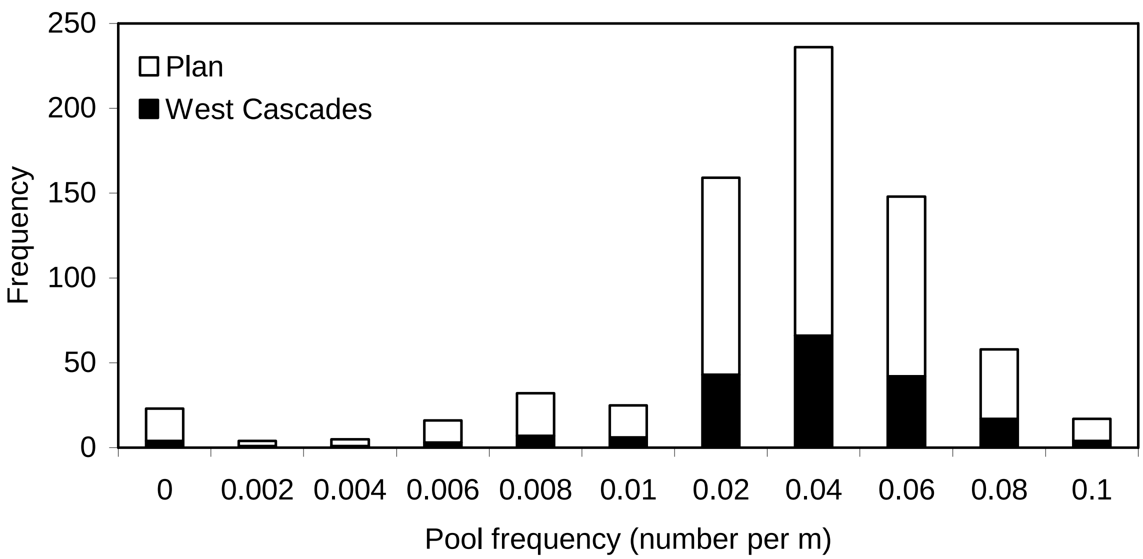


Figure 11. Distribution of pool frequencies in stream reaches in the West Cascades Province and the Northwest Forest Plan area.

Quality Assurance/ Quality Control

The Quality Assurance Program (QAP) report presents seven years (2001–2007) of results and focuses both on the ability of crews to conduct surveys as well non-analytical results of the QAP. Crew surveys were evaluated with signal-to-noise ratios (S:N) and plots of initial surveys against secondary surveys. The former technique is designed to gage the effect of crew measurement accuracy on the ability to detect trends, while the later focuses on inter-crew precision. Non-analytical information addresses issues of data quality control and corrective measures used during data acquisition. Key findings of the report to date are:

- Attributes were judged on the number of years (of six) that they met or exceeded acceptable levels. For trend and consistency, 50 % of the attributes met the indicator criteria at least three of the six years (see Table 5 for discussion).
- The QA program has served the intended purpose of determining how well crews do at deriving the same answer for consistent attribute measurement.
- The QA program has had the unintended consequence of demonstrating several protocols' inability to detect change.
- The results of the analyses indicate that time (across years), which is confounded by annual changes in the field protocols, has an impact on the results of remeasurements.
- The QA program is successful at cleaning the field data and accounting for the errors present.

Table 5. Rating of field protocol attributes with respect to both trend and consistency. For trend, the number of years (of six) that the calculated signal to noise ratio (an indicator of ability to detect trend) met or exceeded a value of four. For consistency, the number of years (of six) that the calculated slope of the line between initial and secondary surveys (within year) was not significantly different than one. Good, fair, and poor represent 5-6 years, 3-4 years, and 0-2 years of the attribute meeting or exceeding the indicator value.

ATTRIBUTE	Overall trend rating	Overall consistency rating
average Bankfull width	Fair	Poor
average Bankfull depth	Poor	Fair
average Bankfull W:D	Poor	Fair
Gradient	Fair	Good
Sinuosity	Poor	Fair
D50	Poor	Fair
D50 without bedrock	Poor	Poor
% Pool tail crest fines	Good	Poor
Wood pieces	Good	Poor
Number of pools	Good	Poor
Residual pool depth	Poor	Poor
Dissolved oxygen	Fair	Poor
Conductivity	Good	Fair
pH	Poor	Fair
Percent salmonids	Good	Fair
Shannon diversity index	Poor	Poor
Species evenness	Poor	Poor

CONTACT INFORMATION

For more information regarding the Aquatic and Riparian Effectiveness Monitoring Program, please contact the following personnel or visit our website at: http://www.reo.gov/monitoring/watershed.

Steve Lanigan	Peter Eldred	Kirsten Gallo	Chris Moyer
Module Lead	GIS Coordinator	Aquatic Ecologist	Fish Biologist
333 SW First Ave.	4077 Research Way	4077 Research Way	4077 Research Way
Portland, OR 97208	Corvallis, OR 97333	Corvallis, OR 97333	Corvallis, OR 97333
503.808.2261	541.750.7078	541.750.7021	541.750.7017
slanigan@fs.fed.us	peldred@fs.fed.us	kgallo@fs.fed.us	cmoyer@fs.fed.us

REFERENCES

Forest ecosystem management and assessment team [FEMAT]. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Portland, OR: U.S. Department of Agriculture; U.S. Department of the Interior [and others]. [Irregular pagination].

Gallo, K., Lanigan, S.H., Eldred, P., [et al.]. 2005. Northwest Forest Plan: The First 10 years (1994-2003): Preliminary assessment of the condition of watersheds. Gen. Tech. Rep. PNW-GTR-647. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 133 p.

Hawkins, C.P., Ostermiller, J., Vinson, M. 2001. Stream invertebrate, periphyton, and environmental sampling associated with biological water quality assessments. Field Protocols. Utah State University, Logan, UT.

Moore, K., Jones, K., Dambacher, J. 1999. Methods for stream habitat surveys, aquatic habitat inventory project, Natural Production Program: Oregon Department of Fish and Wildlife, Corvallis, OR.

Moeur, M., Spies, T., Hemstrom, M. [et al.]. 2005. Status and trends of late-successional and old-growth forests under the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-646. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 142 p.

Peck, D.V., Herlihy, A.T., Hill, B.H., Hughes, R.M., Kaufmann, P.R., Klemm, D.J., Lazorchak, J. M., McCormick, F. H., Peterson, S.A., Ringold, P.L., Magee, T., and Cappaert, M.R. 2006. Environmental Monitoring and Assessment Program-Surface Waters: Western Pilot Study field operations manual for wadeable streams. EPA/620/R-06/003. USEPA. Washington, DC.

Reeves, G.H., Hohler, D.B., Larsen, D.P. [et al.]. 2004. Effectiveness monitoring for the aquatic and riparian component the Northwest Forest Plan: conceptual framework and options. Gen. Tech. Rep. PNW-GTR-577. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

U.S. Department of Agriculture Forest Service, Region 5. 1998. Stream condition inventory guidebook. Version 4.0.

U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management. 1994. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents in the range of the northern spotted owl and standards and guidelines for management of habitat for late-successional and old-growth forest related species in the range of the northern spotted owl. [Place of publication unknown]. 74 p. [plus Attachment A: standards and guidelines].